1090-WP-2-06
30 January 2001

RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS

Meeting #2

Flight Information Services Broadcast (FIS-B) on 1090 MHz

Presented by Vince Orlando

SUMMARY
This information paper presents a briefing that shows how FIS-B could be supported on 1090 MHz. It includes message coding and estimates of channel activity needed to support an assumed level of FIS-B services. **This briefing was prepared by Jonathan Bernays of MIT Lincoln Laboratory for presentation to the Technical Link Assessment Team (TLAT).**

FIS-B Overview

D. Jonathan Bernays
MIT Lincoln Laboratory
27 August 1999

Overview

- Review of discussion, previous baseline FIS-B configuration
- Presentation of strawman FIS-B encoding for broadcast channel with higher error rate than terrestrial channels
- Examples of strawman encoding with recorded weather images
- Preliminary results of uplink squitter reception performance in LA Basin (from Jun 17 data)
- Summary

FIS-B Assumptions (Requirements)

- FIS-B aimed at GA (Part 91) typical aircraft
- FIS-B for advisory use only (no guarantee of delivery)
  - not “real time”
  - not a substitute for airborne sensors, other alerting mechanisms
- Key parameters:
  - update rate - 300 seconds (from feedback of SF21 Tech/Cert Comm)
  - product range (within LOS of transmitting station, ~200 nmi)
  - product mix (based on information available now):

1- (512 pixel x 512 pixel) graphical images (~50,000/image)	50,000
720 nmi x 720 nmi range with 1.25 nmi resolution	
ATIS	2000
Windshear alerts	
	2000
PIREPS/SUA	1000
Total:	55,000

Digital ATIS assumptions

- Use of standardized ICAO dictionary (DLAC) for ATIS encoding
  - expect to encode single airport information with 200 bits
  - information included:

    time, altimeter setting, wx, wind direction and velocity, runway arrival and departure information, remarks.

    Example:

    Hanscom information Q, 1945 Zulu, wind 340 at 25 knots gusting 35 knots, ceiling 1500 scattered, 3500 scattered, 7000 broken, altimeter setting 30.24, arrivals may expect hanscom 3 arrival, ils approach to runway 29, departures may expect runway 5, Hanscom 6 departure. Thunderstorms 5 nmi to the southeast of the field. Moderate bird activity all quadrants of the airport. Taxiways delta and echo closed between romeo and mike.
  - Up to 10 airports may be included in broadcast loop.

PIREPS/SUA Assumptions

- Similar to ATIS, expect to use data dictionary in standard formats to minimize necessary bits.
- Example:
  - time/location/altitude/type aircraft/weather report/remarks
  - 0932Z/5dme northeast of BDR/8500/PA-28/cloud tops 4300, moderate turbulence from grnd to 3500, visibility 5 miles in haze at 8500/lots of buildups to north

Graphical Image Assumptions

- Single image may be encode losslessly with 40K-55K bits
- Modest (imperceptible) detail suppression allows 25% reduction
  - more aggressive filtering yields acceptable images at 50-70% reduction
- Image sizes for lossless encoding of example weather images:

	256 x 256 pixels	512 x 512 pixel
– BDR	24k bits	46K bits
– SUX	21.2k bits	48K
– IAH	13k bits	38K
– RIC	17.4k bits	53K

FIS-B Encoding Algorithm

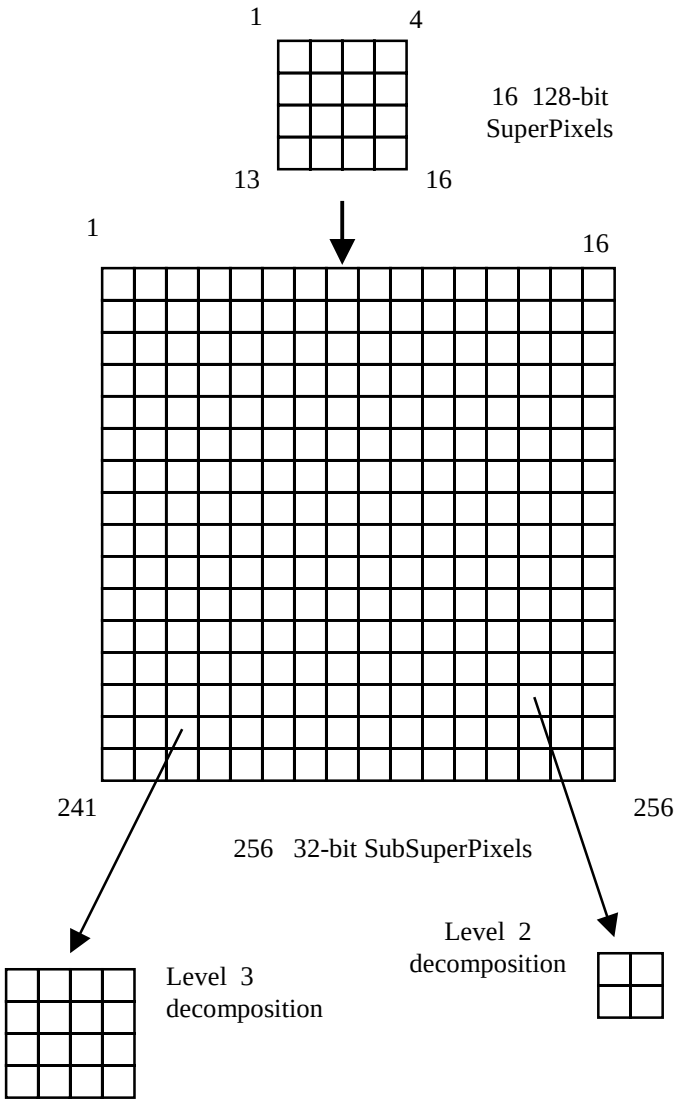
- **Assumptions:**
  - Broadcast loops are identified by time and location
  - Product is 4 level, 512 x 512 pixel precipitation map
  - Minimum number of “critical” packets (2 packets in baseline) essential for message decode
  - All packets may be decoded independently as long as the header packets are received first
  - Partial map may be assembled from the packets that are correctly received and decoded within each broadcast
- **Overview**
  - Encode the 512 x 512 pixel map into 16 SuperPixels, send header packets that include max value in each SuperPixel, Huffman tables, message header information
  - Send subsequent coarse, fine message packets
  - Reconstruct map with header + message packets

Details of FIS-B encoding algorithm

- Start with 512 x 512 pixel image
- Phase I "SuperPixel Encoding":
  - Encode maximum value within each of 16, 128 x 128 "super pixels" into "header squitter"
  - For "super pixels" that contain level 2 or level 3 weather, subdivide:

    if level 3, further subdivide into another 16 blocks (8 pixel x 8 pixel)

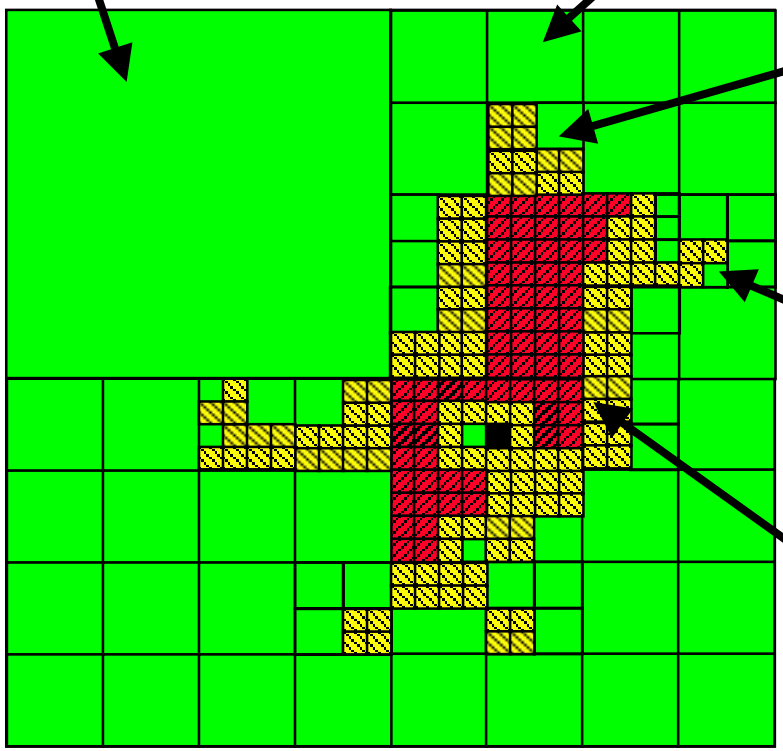
    if level 2 recursively subdivide into 4 blocks until no further blocks contain level 2 weather or a minimum block size of 8 pixels x 8 pixels is reached
  - Maximum of 256 squitters for Phase I encoding, typically 40-50 squitters



Sample Phase I Decomposition

128 pixel x 128 pixel “SuperPixel”

32 pixel x 32 pixel “SubSuperPixel”

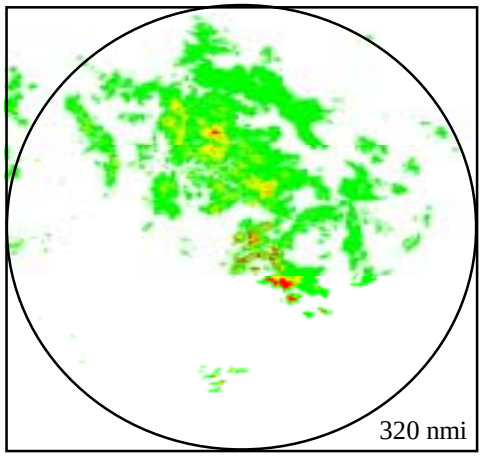


Level 2 weather decomposition into 4 blocks, 16 pixels x 16 pixels each, then recursively into 8 pixel x 8 pixel blocks

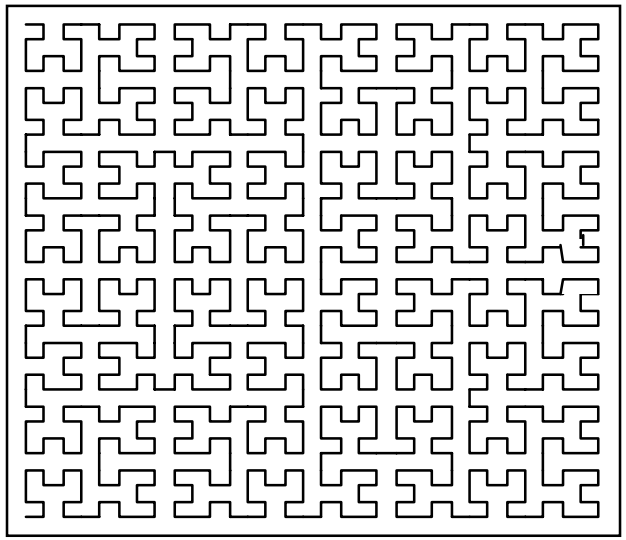
Recursive Level 2 weather decomposition into 4 additional blocks, 8 pixels x 8 pixels each

Level 3 weather decomposition into 16 block, 8 pixels x 8 pixels each

Phase 2 Encoding Details



Input Weather Image



Hilbert Scan Pattern

(Start_Pixel_position, Start_Level, runlength, transition, runlength……..)

Define Huffman Tables, Encode, (using information from SuperPixel values)

Packetization

Series of RunLength Data Squitters

FIS-B Formats

MOPS currently defines DF=18 squitter for non-transponder devices

10010	**CF:3**	**FIS-B Packets:80**	**PI:24**

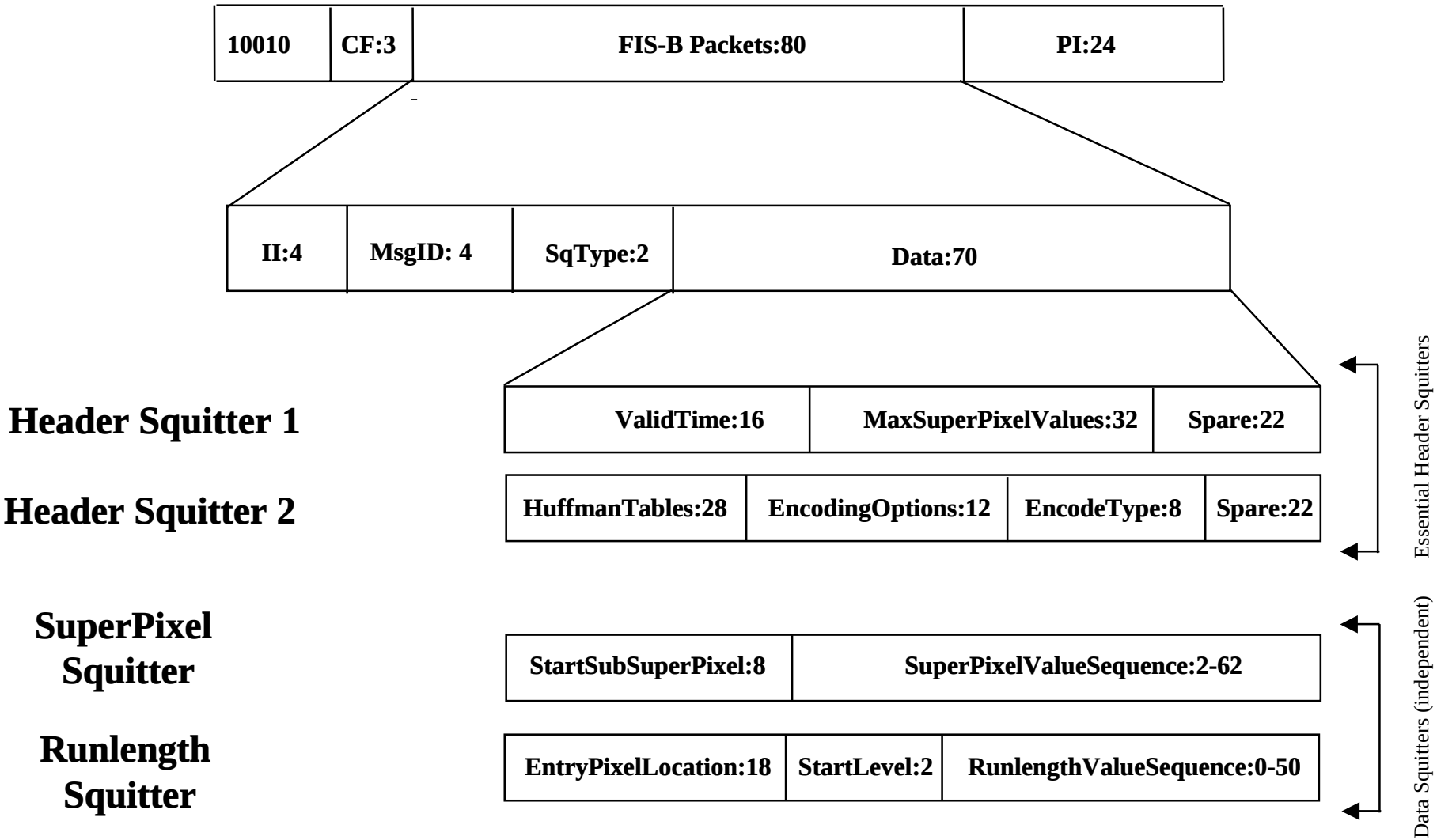
CF Field current definition

- CF=0 indicates standard extended squitter formats from a non-transponder device
- CF=1 to 7 undefined

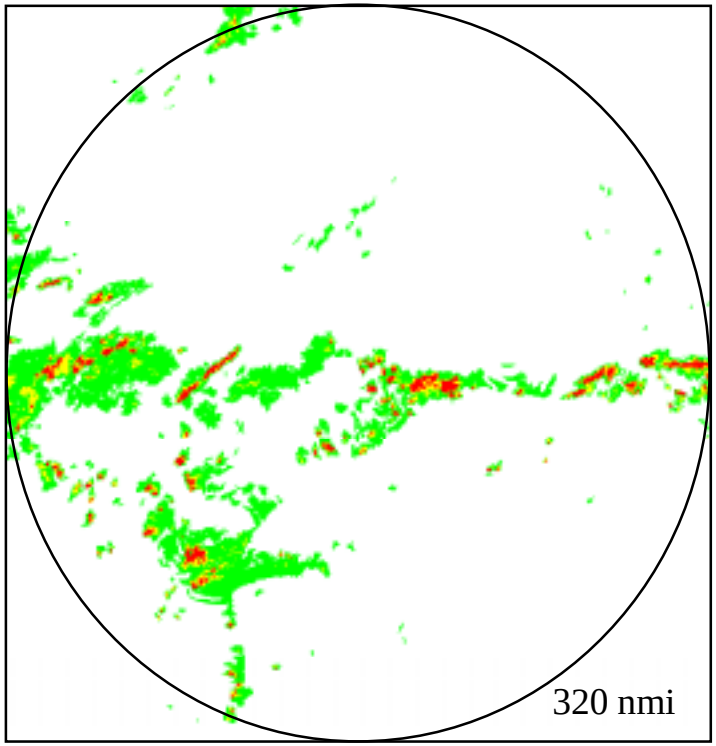
Proposed definition of additional CF field codes as follows:

- CF=1: standard TIS-B
- CF=2: special mode TIS-B
- CF=3: FIS-B

Detailed FIS-B formats

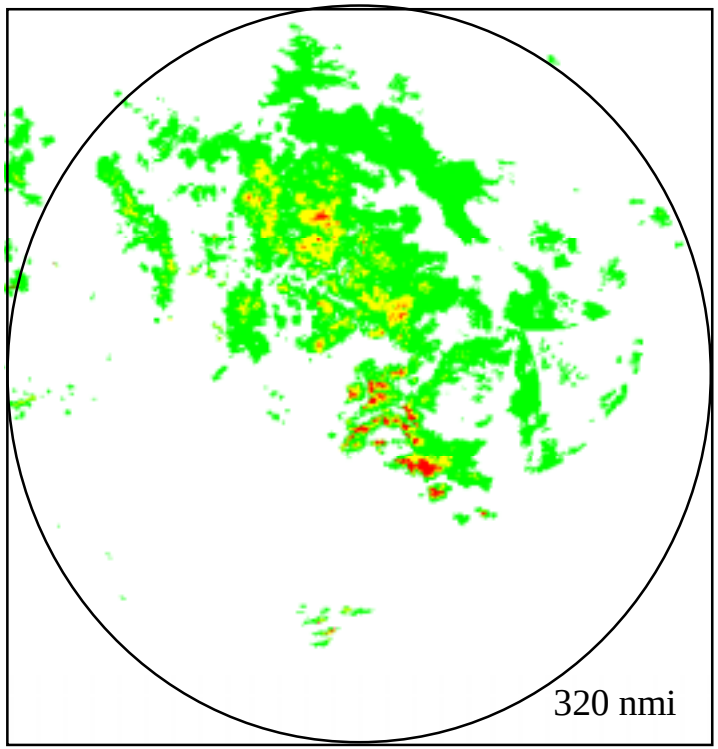


Houston, Texas 1745Z, 15 Jun 99



512 x 512 pixel (2 km per pixel)
38382 bits for WH lossless encoding
891 squitters in total FIS-B encoding
59 squitters for SuperPixel encoding

Bridgeport, Connecticut, 1415Z 11 May 95

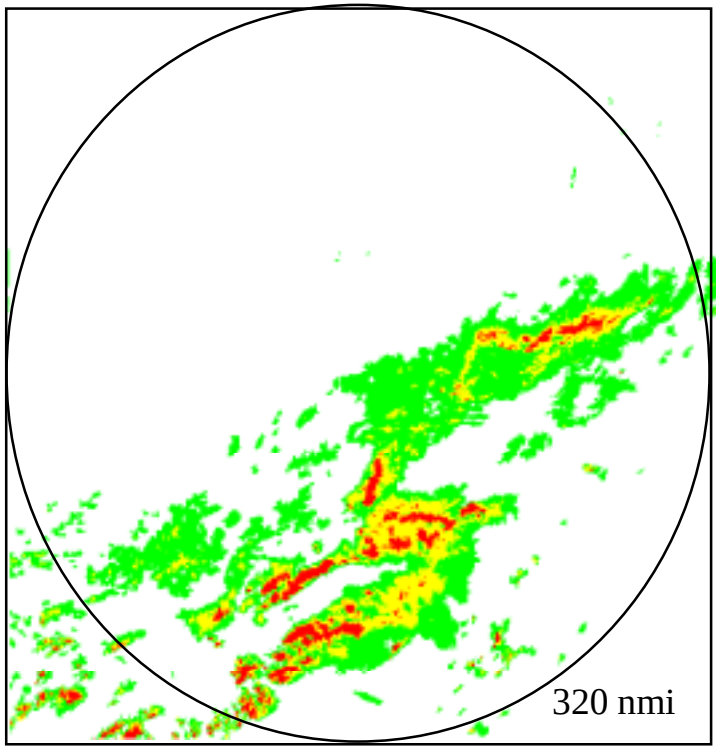


512 x 512 pixel (2 km per pixel)
45921 bits for WH lossless encoding
1060 squitters in total FIS-B encoding
32 squitters in SuperPixel encoding

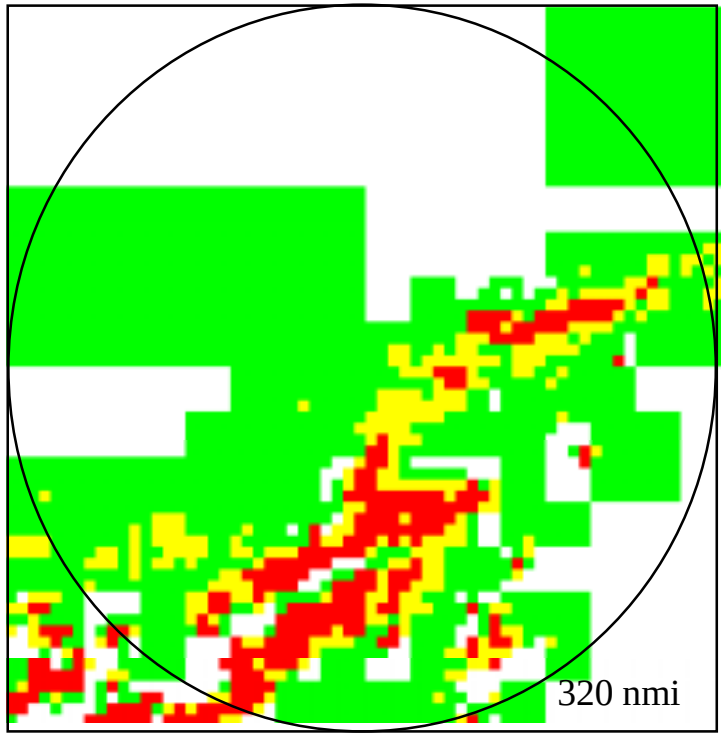
Richmond, Virginia, 1745Z 15 Jun 99

512 x 512 pixel (2 km per pixel)
53058 bits for WH lossless encoding
1191 squitters in total FIS-B encoding
60 squitters in SuperPixel encoding

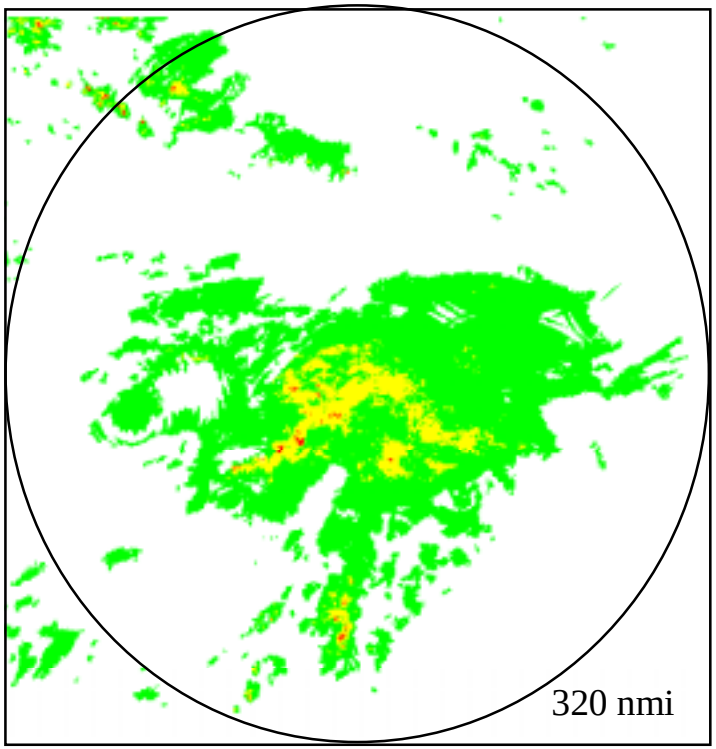
All Bits



SuperPixels Only

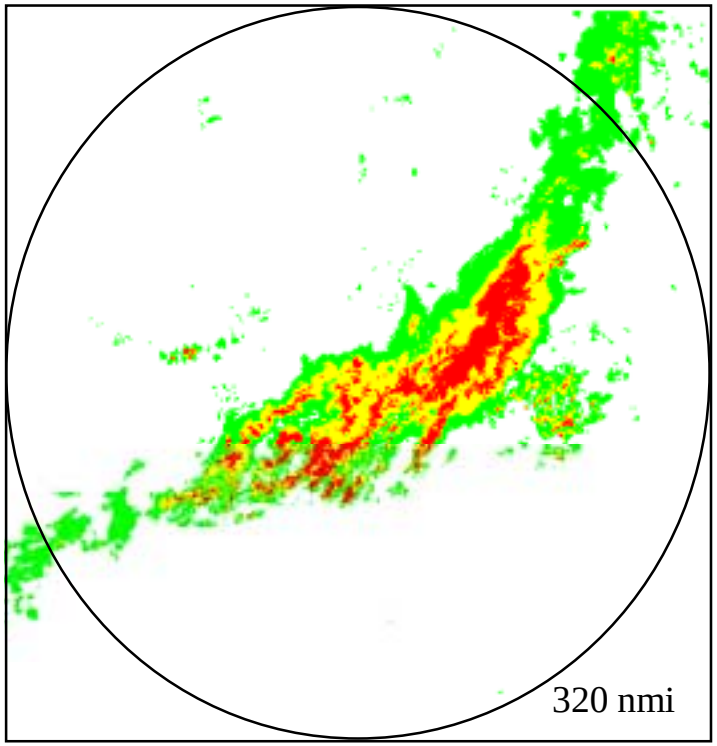


Sioux City, South Dakota, 1745Z 15 Jun 99



512 x 512 pixel (2 km per pixel)
47588 bits for WH lossless encoding
1092 squitters in total FIS-B encoding
31 squitters in SuperPixel encoding

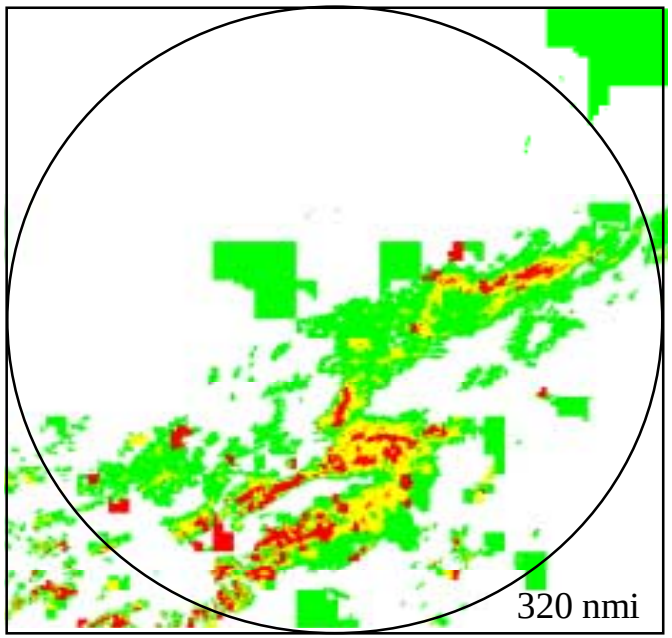
McAlister, Oklahoma, 1430Z 12 Sep 95



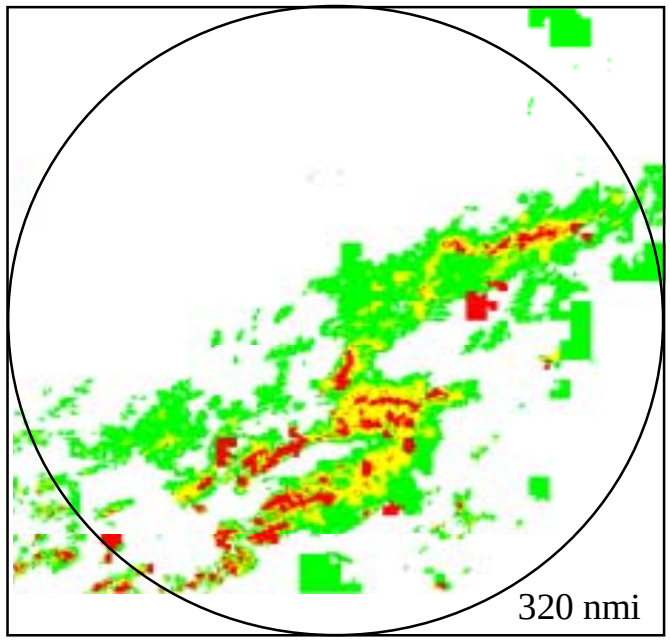
512 x 512 pixel (2 km per pixel)
47247 bits for WH lossless encoding
1052 squitters in total FIS-B encoding
45 squitters in SuperPixel encoding

Examples of Partial Maps

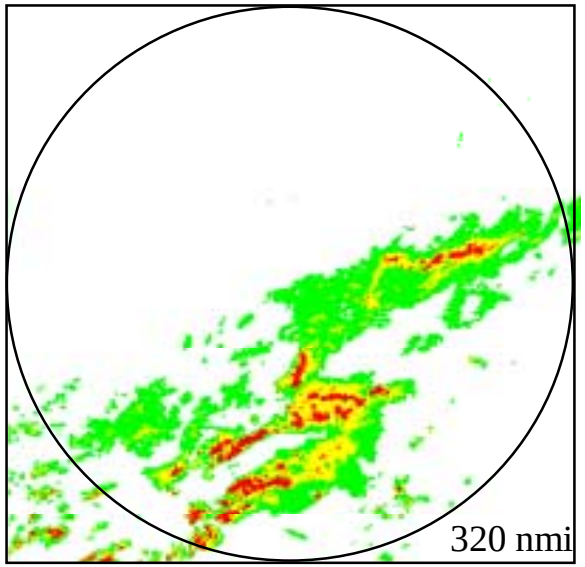
Richmond, Virginia, 1745Z 15 Jun 99
512 x 512 pixel (2 km per pixel)
53058 bits for WH lossless encoding
1191 squitters in total FIS-B encoding
60 squitters in SuperPixel encoding



90%



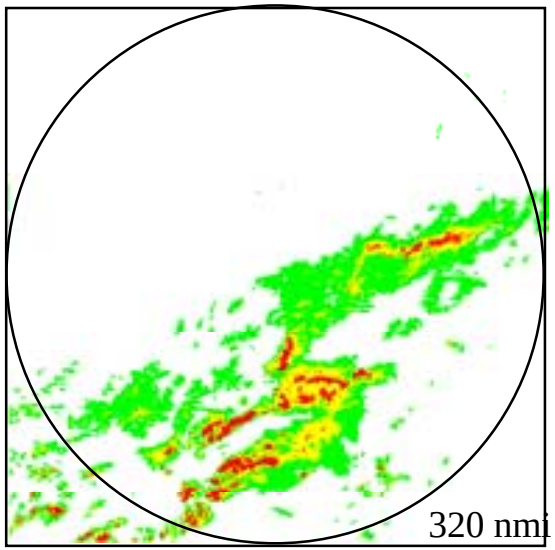
Examples of Filtered Maps

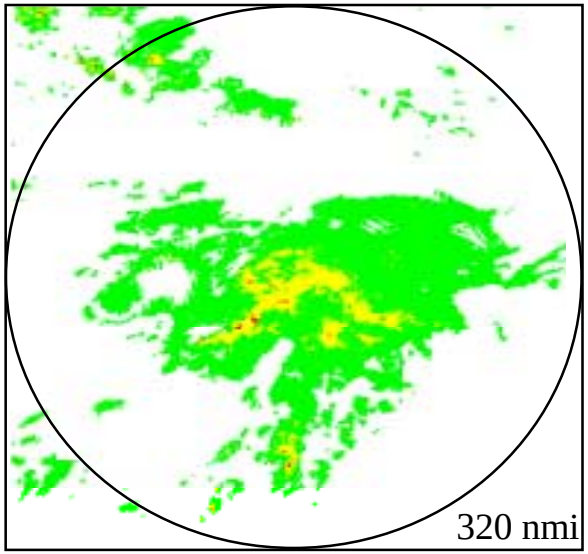


RIC

1191 Squitters,
Lossless

902 Squitters,
Filtered

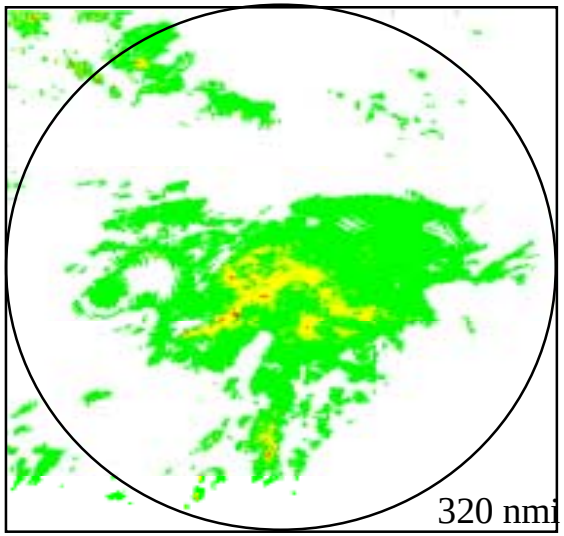




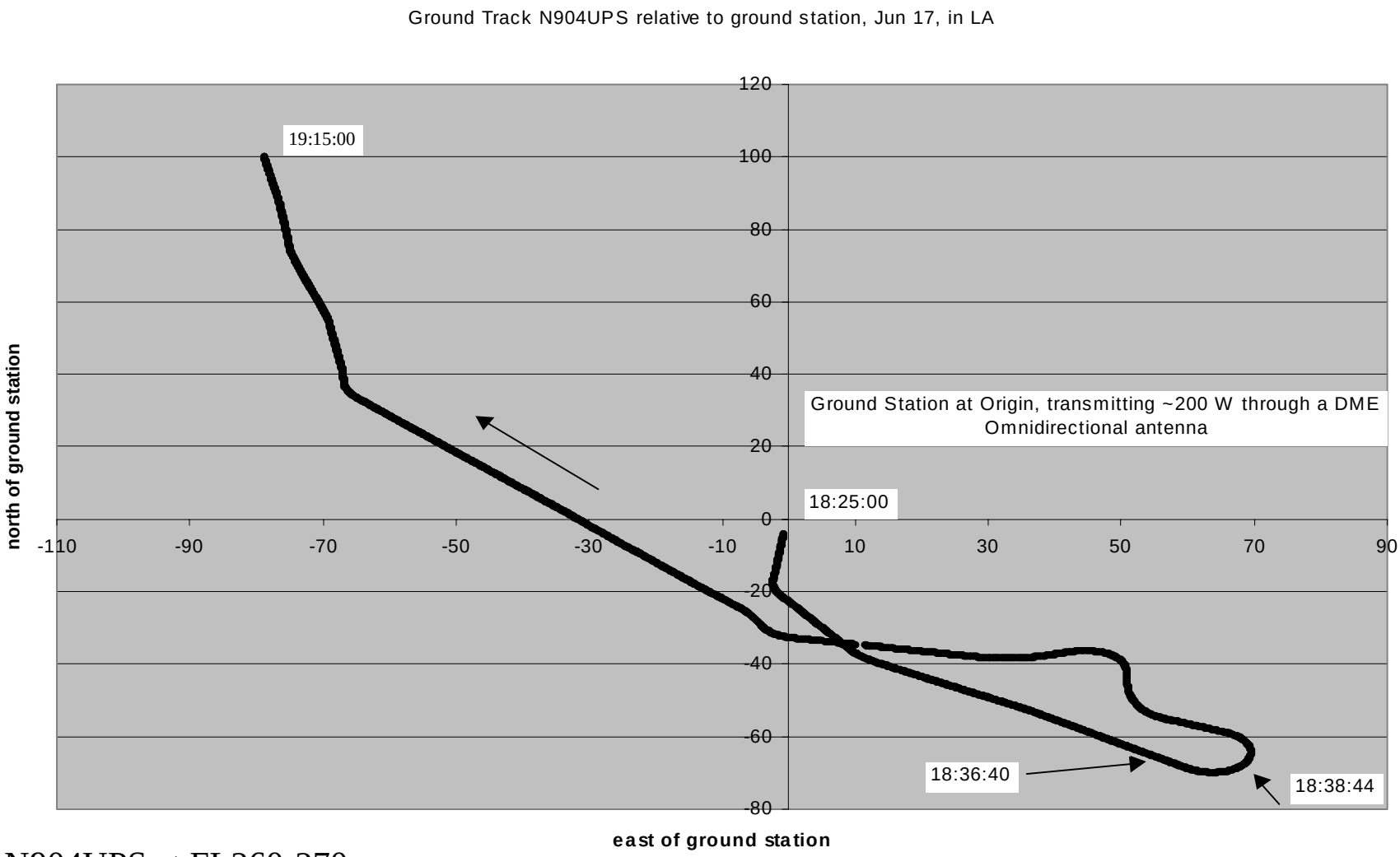
SUX

1092 Squitters,
Lossless

790 Squitters,
Filtered

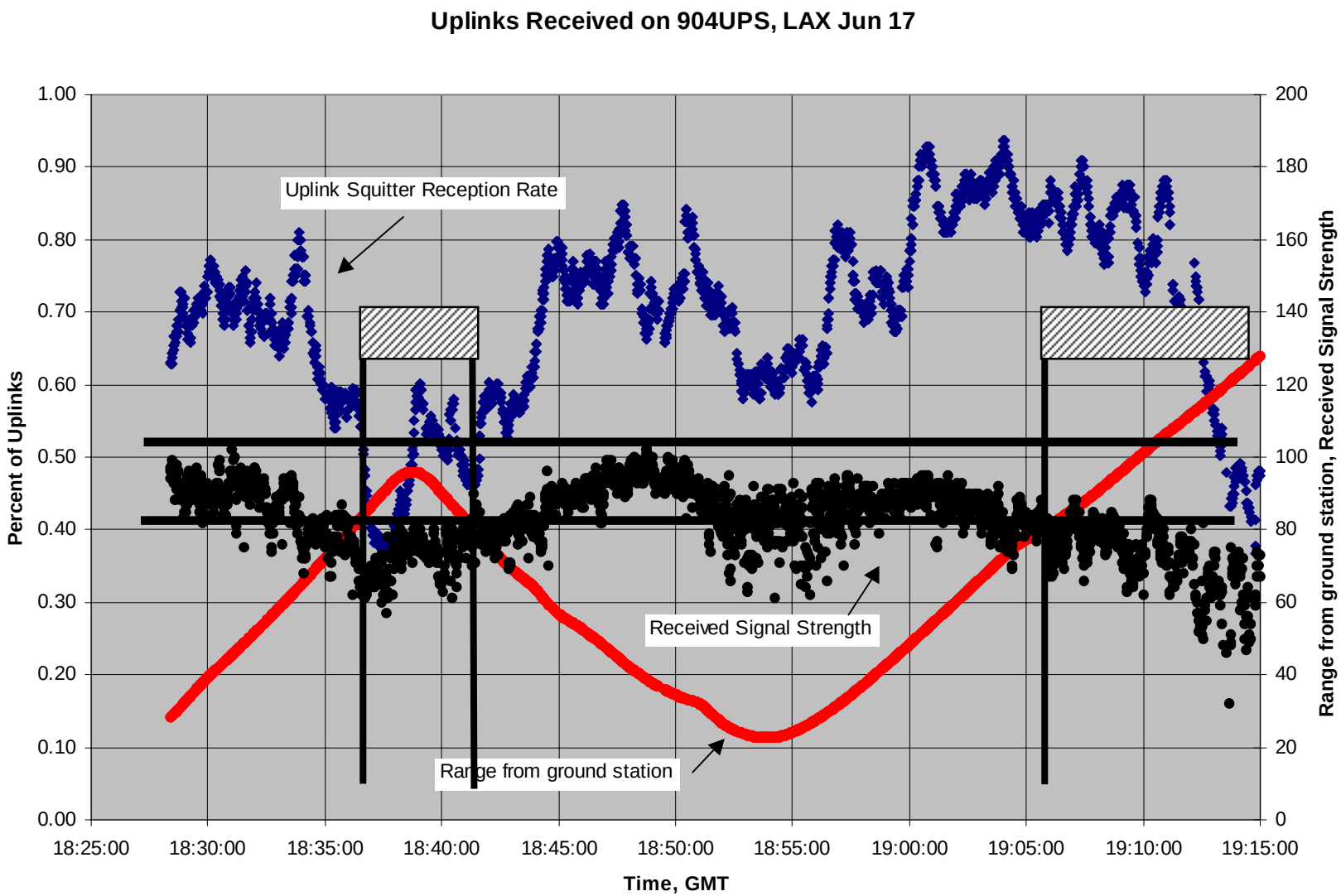


UPS904 Ground Track

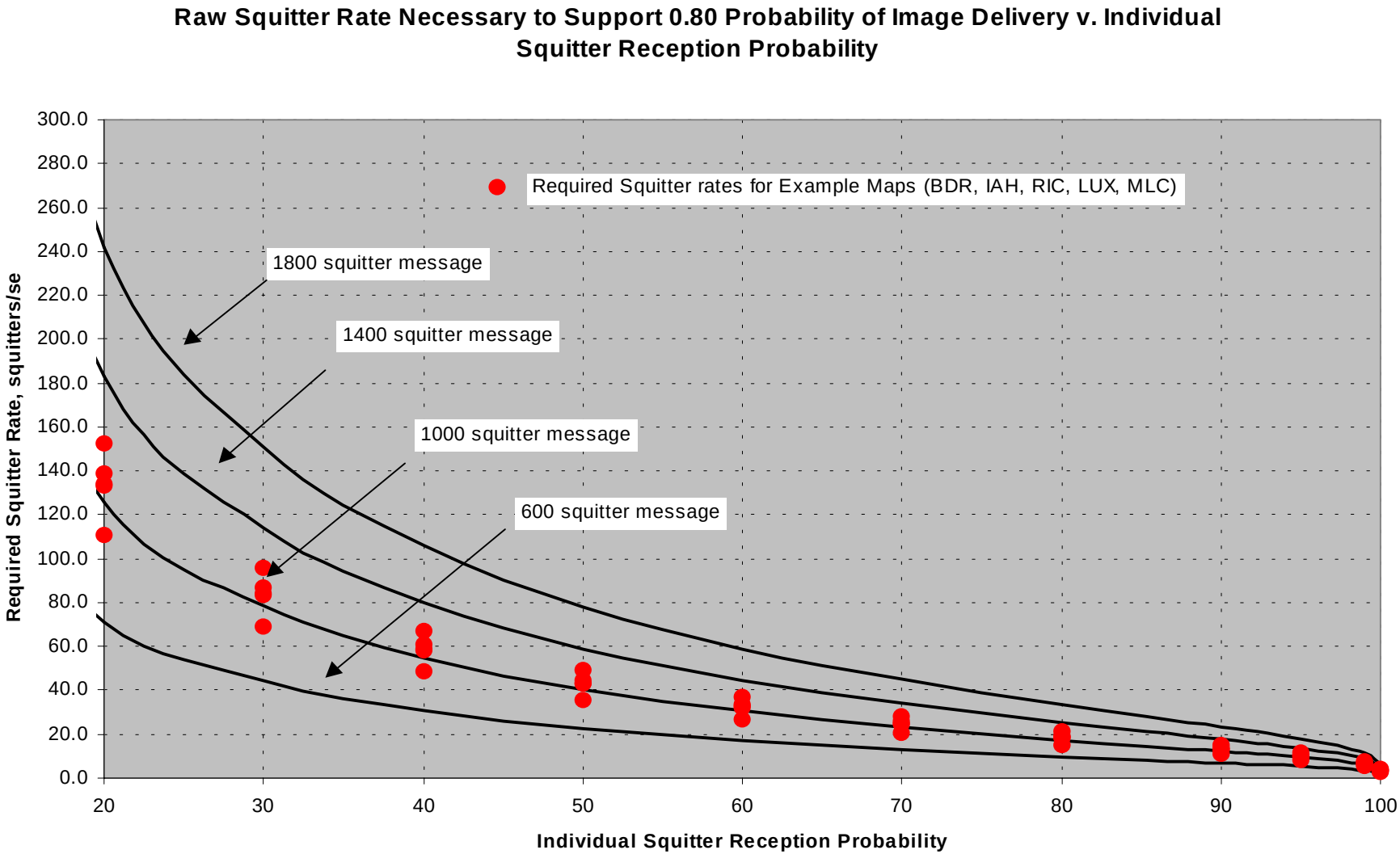


N904UPS at FL260-270

Example Uplink Reception in LA Basin

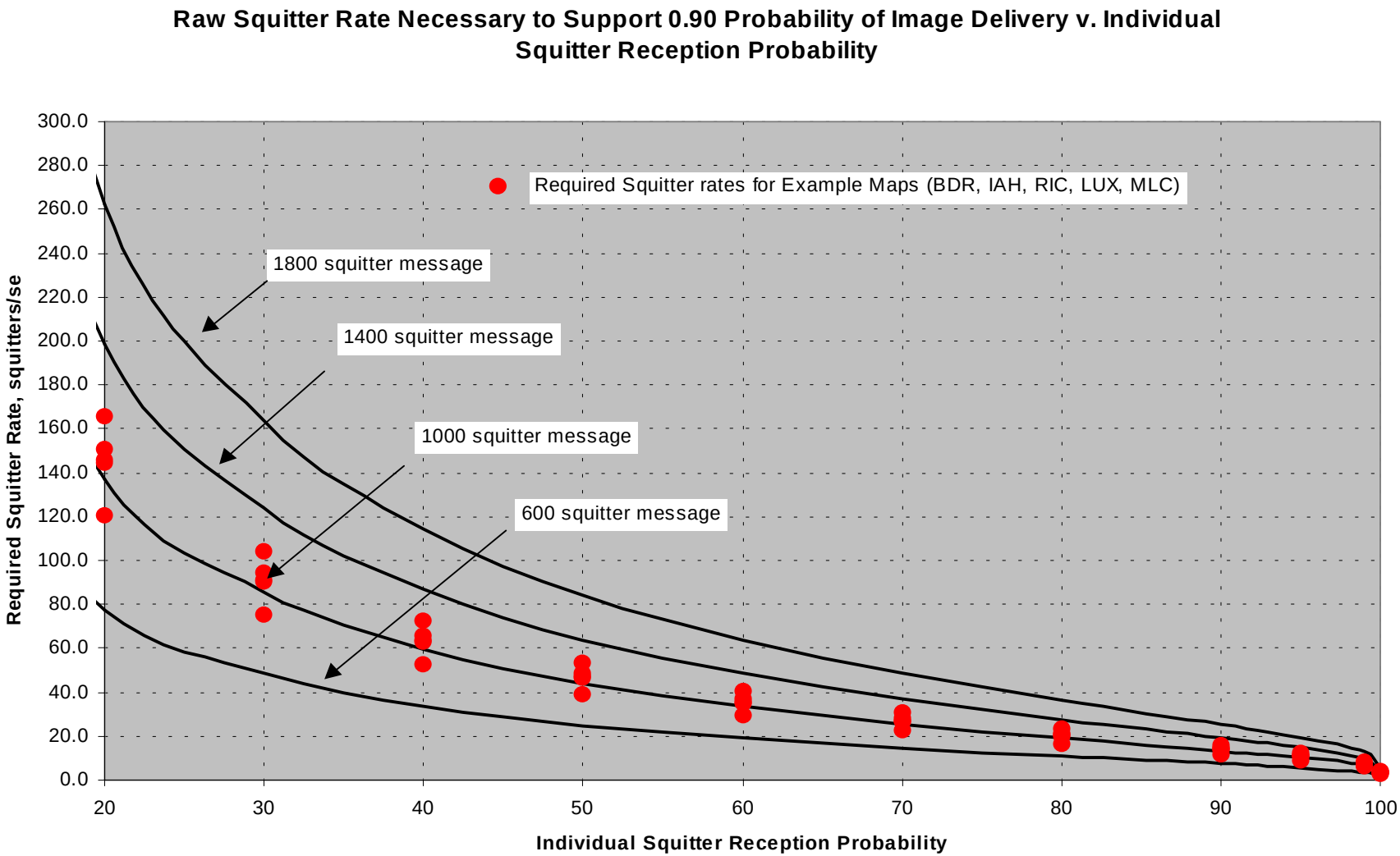


Required Squitter Rates, 80% Image Receipt



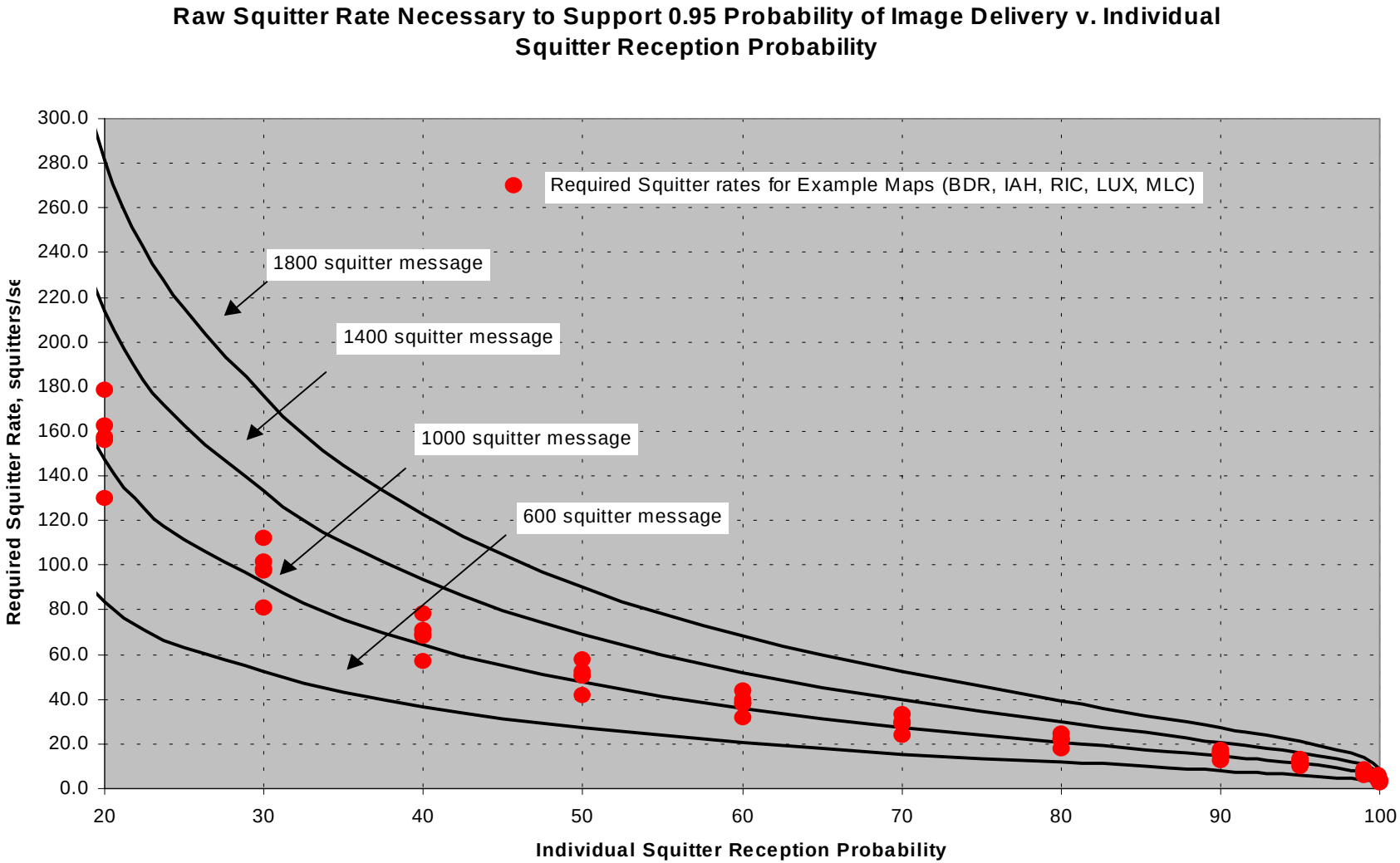
300 second update interval

Required Squitter Rates, 90% Image Receipt



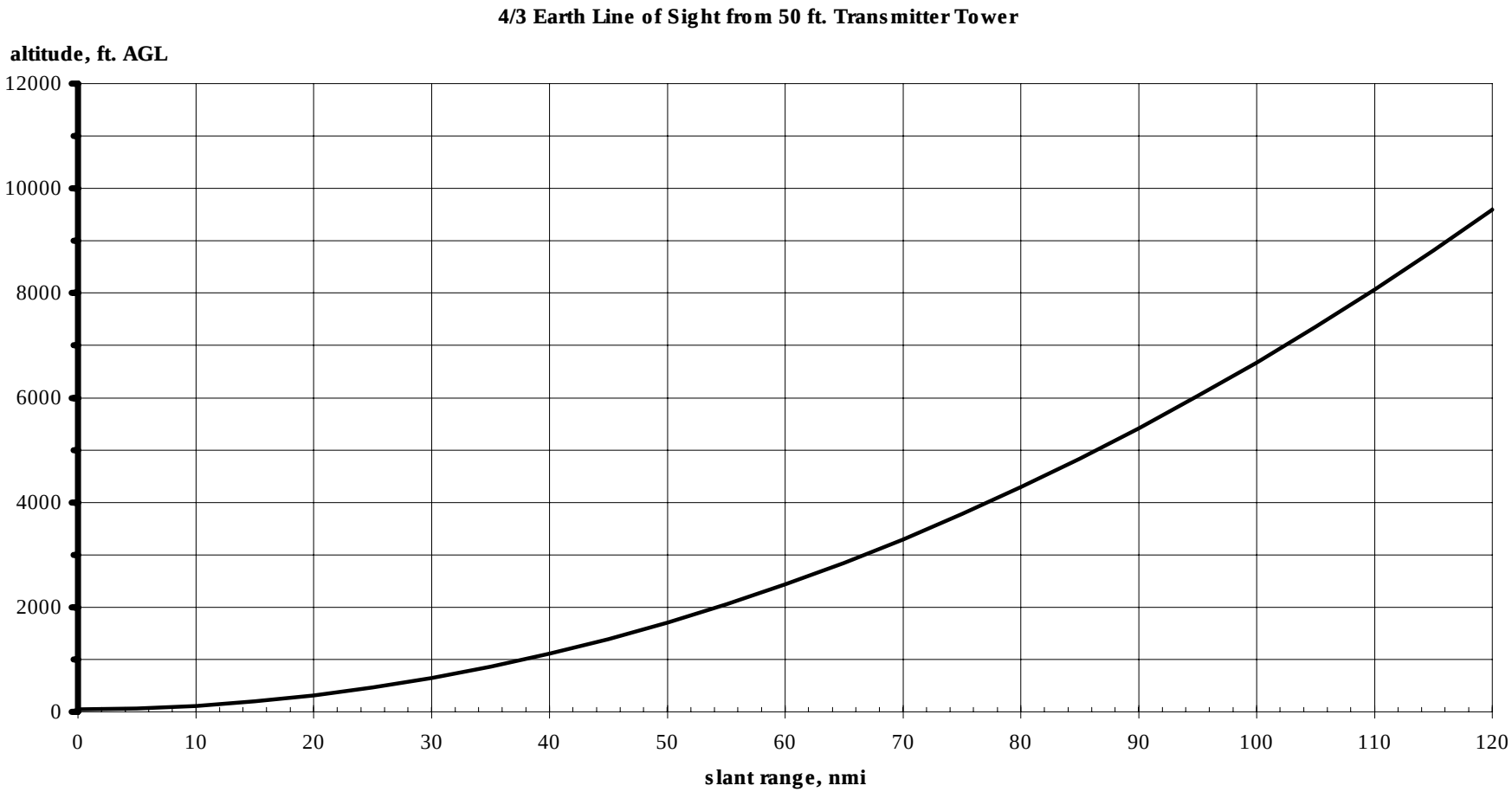
300 second update interval

Required Squitter Rates, 95% Image Receipt



300 second update interval

Line of Sight Limitations



0 degree elevation angle

Strawman FIS-B Link Loading

- Net delivered bits/second ~50K/loop
- Operating with at least 70% uplink reliability, this suggests a raw squitter rate of 20-40 squitters/second is necessary, depending on the required probability of delivery for each map
  - This load is equivalent to 5-10 aircraft squittering with MOPS-compliant equipment
  - This estimate is conservative with respect to:
    - product range
    - update rate
    - resolution
    - use of filtering

Summary

- FIS-B requirements driven by communications channel error rate, desired update rate
- Fault tolerant uplink encoding required in absence of verification of image receipt
  - Strawman technique presented with examples taken from recorded weather images (courtesy of WSI Corp.)
- 700 nmi, 1.25 nmi resolution image with 4 level weather can be encoded in ~1000 1090 MHz squitters
  - Lower resolution, lesser range, selective image filtering all show promise of substantial reduction in squitters/image
  - Preliminary results indicate FIS-B is compatible with 60+ mile range, even in LA Basin

Weather Huffman Encoding Transmission Details (Review)

- Use of Weather Huffman allows greatest efficiency, but remains vulnerable to single bit dropout
  - 20K bits sent in 80 bit packages, requires 250 squitters
  - resend squitters at 7:1 ratio for redundancy
    - number squitters to allow message reassembly
    - distribute redundant squitters uniformly throughout update interval
  - Operation limited to regions where the per squitter success rate is 80%
    - each squitter sent 7x, probability of delivering 250 squitter message is 0.997

Net Squitter rate for FIS-B with WH encoding (Review)

- 5000 bits for text, 40,000 bits for graphical images (two per broadcast loop)
- 45000 bits/600 seconds = 75 bits/second delivered
- 45000 bits total loop length, or 600 packets (including overhead)
- 7:1 redundancy factor to account for interference
- 4200 squitters/600 seconds = 7 squitters/second actual rate